CHAPTER 12. VHF/UHF/SHF DATA/COMMUNICATIONS LINKS FREQUENCY ENGINEERING

1200. PURPOSE. This chapter and its associated appendix provide the criteria for the engineering of frequencies for each of the type of links indicated in the title. It does not supersede or replace existing maintenance or installation instructions, but rather provides only that technical data required to provide the frequency engineering necessary for each facility. Coordination between the frequency engineer and the installation staff is essential to assure system viability. The Radar Microwave Link (RML) is being phased out and replaced with the FR8 Radio Communications Link (RCL) and low density microwave links (LDRCL). References to the RML 1, 2, 3, 4, 5 and 6 have been deleted from this order. ASR will archive the RML technical data as reference material.

1201. FREQUENCY BANDS AVAILABLE FOR RADIO LINKS. Basically, radio frequency link engineering involves two frequency analyses, cosite and intersite. The following bands are available for links as indicated.

FIGURE 12-1. BANDS CURRENTLY USED BY FAA FOR RADIO LINKS

162-174 MHz	Land Mobile*	Very congested band
406.1-420 MHz	Land Mobile*	Very congested band
932-935 MHz	Fixed Station***	LDRCL
941-944 MHz	Fixed Station	LDRCL
1710-1850 MHz	Fixed Station**	LDRCL
7125-8500 MHz	Fixed Station	Radio Communications Link (RCL)
14.4-15.35 GHz	Fixed Station	TV Microwave Link (TML)
21.2-23.6 GHz	Fixed Station	Microwave links

* Specific frequencies are allotted for fixed operations such as Low Level Windshear systems (LLWAS), RMM, MALSR, etc. (See chapter 17.)

** New requirements for radio links will not be satisfied in the 1710-1850 band. Future LDRCL's will utilize 932-935/941-944 MHz, 7125-8500 MHz or 21.2-23.6 GHz. 1710-1755 MHz is to be transferred to the private sector due to Title VI of the Omnibus Reconciliation Act of 1993, on January 1, 1999.

***New spectrum requirements for LLWAS by 1999.

Note: In addition, there are other bands for fixed radio links, such as 2200-2300 MHz, 4400-4990 MHz, 25.25-27.50 GHz, 36.0-38.6 GHz, etc., which also are available for FAA use.

a. The band 7125-8500 MHz is broken up by segments allocated to space communications. Only the subbands 7125-7250, 7300-7900, and 8025-8500 MHz are available for fixed PTP links. NOTE: The FR8 RCL will not operate in the 8400 to 8500 MHz band.

b. The band 14.5-15.35 GHz is broken into three sections. The portion 14.7145-15.1365 GHz is allocated to other services on a primary basis. This subband must be avoided in planning Television Microwave Link (TML) systems.

c. Because of the wide variety of microwave equipment used by FAA, detailed engineering criteria are not provided for all such systems. Detailed engineering criteria are provided for the FR8 because of its extensive use. In general, when doing spectrum engineering for microwave systems, the intersite engineering should be done first, since it is straightforward. When analyzing the cosite situation, care must be taken that image frequencies of the system are considered. The appropriate manufacturer's equipment specifications should be consulted and the general procedures of paragraph 1204 followed.

1202. INTERNATIONAL COORDINATION REQUIREMENTS. When systems are to be designed for use within 100 nmi of the Canadian or Mexican borders, ASR should be notified very early in the project. There are international agreements with Canada and Mexico that require coordination. Early coordination can prevent having to vacate a planned frequency group when it is found to conflict with their operations.

1203. TECHNICAL STANDARDS FOR LINKS. See Chapter 5 of the NTIA manual. Technical data for IRAC applications for U/SHF systems are found in the appendix.

1204. THE GENERAL PROCEDURE FOR MICROWAVE LINK INTERSITE FREQUENCY ENGINEERING is basically an orderly step-by-step compilation of all the parameters of all potentially competing systems. It simply consists of carefully examining every parameter that would affect the overall RF path from a transmitter output to a receiver input. Essentially, the frequency is unimportant to the procedure because the procedure is the same for 900 MHz as it is for 21 GHz. While F & E sets the physical path, the frequency engineer must check the spectrum compatibility both as a potential interferer to other established systems (culprit) and as a potential receiver of RFI from other systems (victim). See figure 12-3. The following is a general discussion of the detailed procedure followed by a simple format which is intended to assist in assuring that all parameters are considered as well as providing a study record of each system analysis.

a. While the actual site path will be engineered by F & E, the frequency engineer must be sufficiently familiar with certain of the engineering parameters to assure that the frequencies engineered will work with the system.

b. Cosite considerations. Of particular importance are other microwave systems. For instance, the second harmonic of a good portion of the 7125-8500 MHz band falls into the 14.50-15.35 GHz band. In addition, FAA is not always able to site its equipment on an exclusive FAA site, so that any other users' equipment must be considered, both for interference to and from.

c. Intersite and near parallel path considerations. The site shall be frequency engineered by checking the GMF carefully for the full bandwidth of FAA's equipment and add to that the bandwidth of any other user's equipment operating in the area. The standards for determining how much signal is to be expected to be received from another user nearby or near-frequency are dependent on the RF/IF bandpass characteristics of the victim Rx. Determination of the required azimuthal separation from other users is also a matter of parameters.

d. From the transmitter end, there are several parameters to be considered.

(1) Transmitter output power, specified in dBm, normally a positive value.

(2) Waveguide (feedline) power loss, in dB, always a negative value.

(3) Antenna gain in dB is always a positive value. However, the value for any given azimuth can vary considerably from other azimuths. At microwave frequencies for links, high gain directive antennas are a necessity. While there is a main beam "on the nose" peak gain, often in the range of 30 dB to 40 dB forward, only a few degrees off the main beam azimuth, the gain is reduced considerably, to as much as -20 to -30 dB. It is essential that the radiation pattern specified by the antenna manufacturer be available for determining the gain in the desired azimuth.

(4) Parabolic antenna gain calculations are approximated by a simple formula. Parabolic antennas are considered to be between 55 percent and 65 percent efficient. This general formula is handy for nonstandard size reflectors and for frequencies not commonly used for RCL and TML. A nomograph for parabolic antenna gains is found in the appendix. Assuming the nominal 55 percent value, the gain would be:

$$\boxed{G_{dB} = 20 \log D + 20 \log f + 7.5}$$

Where:

G_{dB} = gain over isotropic, in dBi
f = frequency in GHz
D = parabolic reflector diameter, in feet

Assuming a 6¢ diameter reflector at 7.700 GHz,

G = 15.56 + 17.73 + 7.5

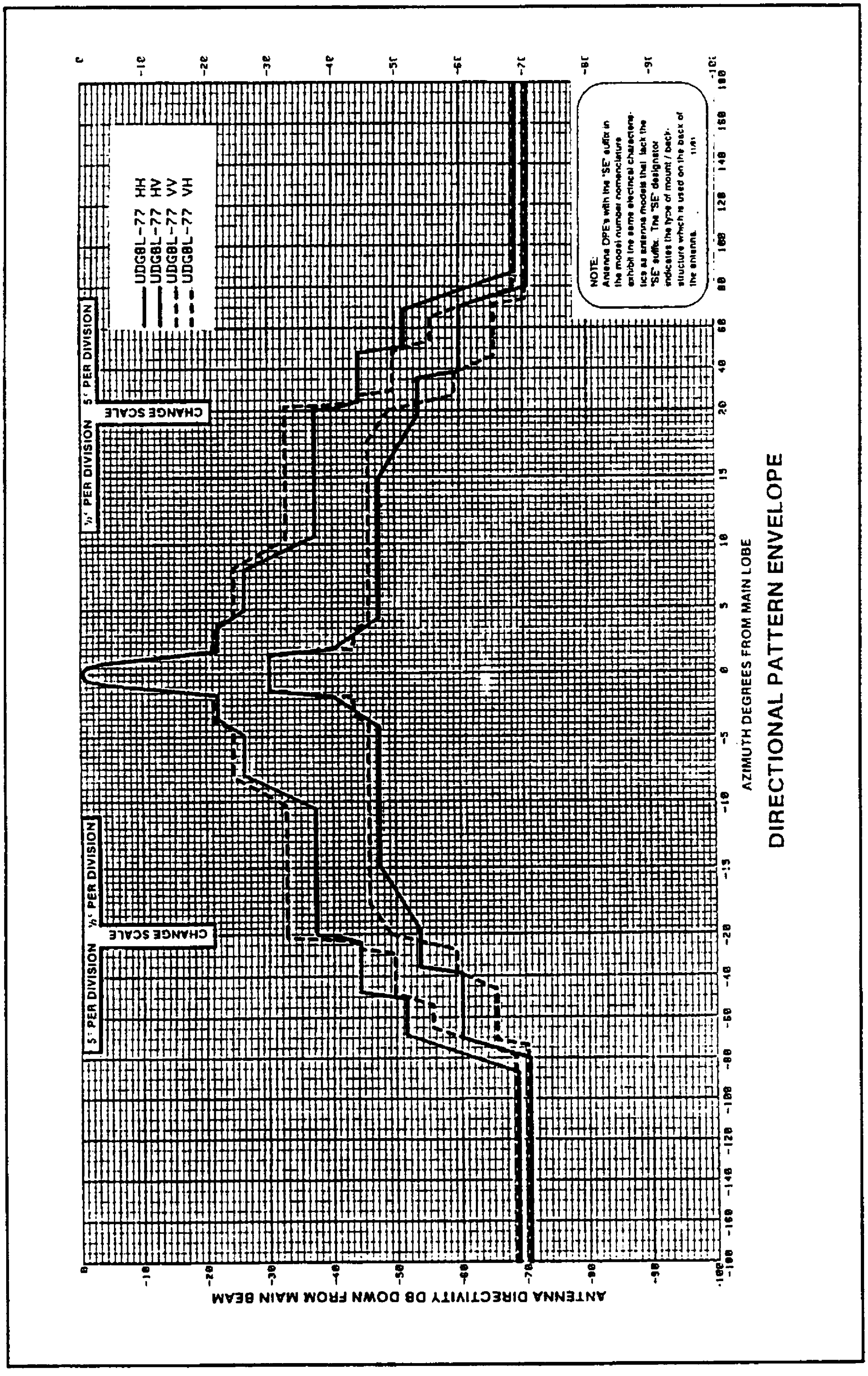
= **40.79 dBi, or approximately 41 dBi**

(a) The forward gain of a highly directional antenna is usually specified by the manufacturer in decibels above an isotropic antenna (dBi) or decibels above a dipole antenna (dBd), with dBd representing a value of 2.1 dB above dBi.

(b) The radiation pattern plot is always shown in the manufacturer's instruction book or specification sheet. This plot may be polar or linear, but both are shown with the main beam at 0 dB and all side lobes shown as values "down" from the main beam reference gain value.

(c) The actual gain of the antenna at any given azimuth other than the primary main beam is that value shown on the plot for the selected azimuth subtracted from the rated main beam gain. For instance, a certain parabolic antenna is rated by the manufacturer at 43 dBd gain. The plot normally shows the main beam at 0°, which represents the 43 dBd gain value. See figure 12-2. Use the HH plot, the upper solid line curve. Looking at the plot at 15° (the azimuth of the victim receiver), it is noted that at that azimuth, a minor lobe has a value of -37 dBd. Thus, the gain in the direction of 15° from the azimuth of the main beam would be a value of 43 - 37 = 6 dBd. That value of 6 dBd is what is used as the "on azimuth" gain for subparagraph (3) above.

FIGURE 12-2. TYPICAL PARABOLIC MICROWAVE ANTENNA RADIATION PATTERN



e. Propagation loss due to distance is a necessary tool for the frequency engineer to assure that the transmitter (Tx) power, the antenna gain, minus the free space loss, plus the receiver (Rx) sensitivity all add up to a usable path. In addition, calculation is needed to determine the level of suspected signal in the vicinity of any competing user on the frequency engineered, for compatibility. Free space propagation loss is not obtainable on the earth, due to atmospheric losses, reflections, etc. But using the basic free-space propagation loss formula is as good an approximation as can be gained without actually putting a signal on the air and measuring it at the receiving location. That free space loss formula is:

$$\boxed{L_{fs}(dB) = 37.8 + 20 \log f + 20 \log d}$$

where: L_{fs} = free space loss, in dB

f = frequency, in MHz

d = distance in nmi
(for statute miles, the constant 37.8 changes to 36.6)

Assuming a 30 nmi path at 7700 MHz,

L_{fs} = 37.8 + 77.7 + 29.5

= **145 dB**

f. A nomograph for space loss is found in the appendix.

g. From the receiver end, there are other parameters to be considered.

(1) The receiver minimum signal level required for satisfactory operation. This value should have already been determined by F & E in their siting study to assure adequate signal at the receiver at all times. This level is always a negative dBm value. It is specified by the manufacturer.

(2) The receiver system interference susceptibility level is specified by the manufacturer in the system instruction manual or specification sheet. This value is usually in the form of a graph curve with dBm level as ordinate and frequency as abscissa. See the appendix for typical curves. This value in dBm is the value that must ultimately be checked against the culprit's signal level at the victim receiver input terminals to determine whether RFI is anticipated.

(3) The receiving antenna gain in dB at the azimuth of the culprit incoming signal. That gain is determined in the same manner as for the transmitting antenna in subparagraph a.(3), above.

(4) The receiving waveguide (feedline) loss, always a negative value, in dB. This is determined from the waveguide or feedline manufacturer's specification sheet.

h. The path fade margin is the one variable in the parameters. It is the loss of signal level at the receiver from variable propagation losses, such as atmospheric moisture, air particle content, etc. The manufacturer of the system will specify the path margin normally required to assure adequate signal from the desired source to the victim receiver. While there is some variance among manufacturers and with frequency (higher bands are more subject to these path fade problems), a manufacturer frequently will specify a 10 dB fade margin. That is, under normal conditions, to assure that the minimum required signal is received by the desired receiver from the desired transmitter during path fade conditions, an additional level of protection is engineered into the siting of the units of the system. In this frequency compatibility study, however, a 15 dB D/U protection value shall be used which includes the path fade and other parameters not absolute. See figure 12-3.

FIGURE 12-3. POWER BUDGET STUDY FOR A MICROWAVE LINK

1. Culprit transmitter power	(+) _______ dBm
2. Culprit transmitter waveguide or feedline loss	(–) _______ dB
3. Culprit transmitter antenna gain in the direction of the victim receiver. [1204 a. (3) (c)]	
a. Main beam gain of the antenna	(+) _______ dB
b. Off-azimuth loss in the direction of the victim	(–) _______ dB
c. Total culprit antenna gain in the direction of victim (sum of a. and b. above)	(±) _______ dB
4. Free space propagation loss. [1204 b.]	(–) _______ dB
5. Victim receiver antenna gain in the direction of the culprit transmitter. [1204 a. (3) (c)]	
a. Main beam gain of the antenna	(+) _______ dB
b. Off-azimuth loss in the direction of the culprit	(–) _______ dB
c. Total victim antenna gain in the direction of culprit (sum of a. and b. above)	(±) _______ dB
6. Victim receiver waveguide or feedline loss	(–) _______ dB
7. Culprit signal level at victim receiver input **(TOTAL)**	(±) _______ dBm
8. Victim receiver RFI susceptibility level. [1204 c. (2)]	(–) _______ dBm
9. Difference between 8. and 9.	(±) _______ dB

The value of item 9 must be -15 dB or less (more negative) for interference-free operation of the link. A 15 dB safety margin, over and above all other calculations, should be provided for the receiver, to assure a positive D/U ratio under all conditions, including path fades.

i. Desired versus Undesired. When engineering a link frequency for FAA, the FAA transmitter is the "undesired" culprit. All other receivers in place within RLOS (or at least 40 nmi) and within frequency range must be checked as the "desired," or victim. When checking the FAA receiver situation, any other system transmitter within the same bounds is the culprit. Both situations, FAA as a victim and a culprit, must show adequate protection before the frequency(ies) can be submitted to ASR for approval. If another agency is frequency engineering a new system and an FAA system is within interference bounds, the other agency must assure protection. In some bands, that agency is required to coordinate with the FAA to verify protection assurance. Even in the bands not requiring IRAC coordination notices, it is wise to verify before approving or coordinating.

j. The most practical method to accomplish the study is to use these tools:

(1) A topographical or sectional map. These maps are ideal because they permit map-siting the systems accurately by coordinates. It is then easy to draw a straight line between the two systems and measure the azimuth deviation from the respective antennas' azimuths heading for their own system.

(2) The AFM CIRCLE program will permit quick and easy access to all systems within the frequency and distance ranges desired for the study.

(3) The AFM bearing/distance program will also provide quick and accurate azimuths and distances between culprit and victim sites.

(4) Note that the final selection of the frequency(ies) may depend on terrain factors which are not easily quantified but which may be apparent from a site survey or analysis of a topographical map.

(5) Use the format of figure 12-3 to determine the power budget and the D/U.

k. Many new FAA microwave systems use digital radios. Experience and studies have shown that digital radio receivers are typically less resistant to RFI than older analog radio systems. It is essential that special care be taken to assure that digital radios sited at FAA installations, especially those near high power radars, are frequency engineered carefully and that the potential impact of nearby emitters, particularly radars, are taken into account. If questions arise concerning proper siting of digital radios, contact ASR for further information and/or bench tests to determine appropriate criteria. It should be noted that nominally up to 10 dB of additional margin may be required for digital receivers as compared to an equivalent analog receiver.

1205. FREQUENCY ENGINEERING FOR THE 932-935 AND 941-944 MHZ BANDS. Engineering of LDRCL in these bands is straightforward. The channeling plan for 12.5-, 25- and 200 kHz assignments in these bands and other constraints on their use are found in NTIA Manual, Chapter 4. Because FAA uses only single links in these bands, cosite engineering for same-frequency band equipment is not needed. Intersite engineering will utilize procedures found in paragraph 1204, as well as criteria in NTIA Manual, Chapter 4.

1206. FREQUENCY ENGINEERING FOR THE 1710-1850 MHZ BAND. As directed by Title VI of the Omnibus Budget Reconciliation Act of 1993, the 1710-1755 MHz portion of this band will be transferred to the private sector on January 1, 1999. FAA assignments in the 1710-1850 MHz band which are outside of a 150 km radius of the 25 largest cities in the U.S. are "grandfathered" and will be allowed to remain. However, it is FAA policy that there will be no further FAA assignments in the 1710-1755 MHz band. No standard frequency plan exists for this band. Refer to Paragraph 1204 for a general analysis of microwave link engineering.

a. Cosite frequency engineering.

(1) Transmitter-to-transmitter (Tx/Tx) frequency separation shall be at least 30 MHz.

(2) Transmitter-to-receiver (Tx/Rx) frequency separation shall be at least 40 MHz.

(3) Receiver-to-receiver (Rx/Rx) frequency separation shall be at least 15 MHz.

b. Intersite frequency engineering. To assure that other microwave systems in the area do not cause interference (or in order to determine that FAA systems will not cause interference to other agencies' systems), the following procedure shall be used.

(1) Using the AFM CIRCLE program, determine all microwave systems within at least 40 nmi of the proposed site.

(2) Using the AFM bearing/distance program, and taking into account the beamwidths of the respective transmit and receive antennas, determine all microwave systems which could be an interference source or victim of the proposed site.

(3) Using the procedure given in figure 12-3, determine whether potential interferers or victims should be analyzed further.

1207. FREQUENCY ENGINEERING FOR RCL IN THE 7125-8500 MHZ BAND. This process consists of two separate criteria. The first considers the FR8 equipment requirements. Note that the FR8 equipment is limited to 7125-8400 MHz. The second concerns microwave link general engineering and is discussed in paragraph 1204.

a. Cosite frequency engineering.

(1). The FR8 equipment frequency selection criteria consists of seven tests. These test apply to the Tx's and Rx's using a common wave guide and antenna configuration.

Test 1. **Space bands** - must be located outside of bands 7250-7300 and 7900-8025 MHz.

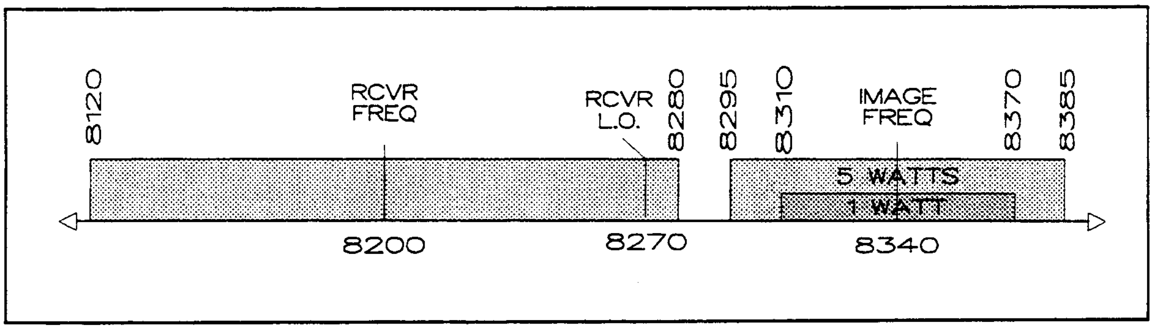
Test 2. **Rx local oscillator (LO)** - must be within the band 7125-8400 MHz.

Test 3. **Tx/Tx and Rx/Rx separation** - a minimum of 60 MHz.

Test 4. **Tx/Rx separation** - Tx frequency must have at least 80 MHz separation from the Rx input frequency. If the Rx is at 8200, then a Tx is not permitted between 8120-8280, based on this test.

Test 5. **Image frequency protection - For a 1 W Tx**, the Tx output frequency must have at least 30 MHz separation from the image frequency; i.e., if the Rx is at 8200 and the Rx LO at 8270, then the Rx image frequency is 8340. The Tx must then not be within the 8310-8370 range, based on this test. For a low side Rx LO at 8130, the Rx image frequency is 8060. A Tx is not permitted within the 8030-8090 range, based on this test. **For a 5 W Tx**, the Tx output frequency must have at least 45 MHz separation from the Rx image frequency. **If an enhanced Rx RF input is installed**, both 1 W and 5 W Tx's output frequency must have at least 15 MHz separation from the Rx image frequency. See figure 12-4.

FIGURE 12-4. EXAMPLE OF TESTS 4 AND 5 PROHIBITED ZONES



Test 6. **The transmitter local oscillator (Tx LO**) must be >30 MHz from other Rx(s) within the hop. NOTE: TX LO = RX LO, i.e. TX = 8270, TX LO = 8270; no other RX permitted between 8240-8300.

Test 7. **For a 1 W Tx**, a third-order intermod frequency is not permitted within 15 MHz of the Rx input frequencies. **For a 5 W Tx**, a third-order intermod frequency is not permitted within 30 MHz of the Rx input frequencies.

(2) Once the 7 tests in subparagraph (1) above have been satisfied for the Tx's and Rx's on a common antenna, the back-to-back coupling must be considered. Back-to-back coupling is the fraction of power received by a second antenna located on the same tower but facing in a different direction from the Tx antenna and using a separate wave guide. The following specifications assume an angular azimuth separation of at least 15 degrees.

(a) For a 1 W Tx with a standard antenna, the Tx output frequencies must be separated from other cosite Rx frequencies by at least 40 MHz.

(b) For a 5 W Tx with a standard antenna, 45 MHz.

(c) For a 1 W or 5 W Tx with a high performance antenna, 25 MHz.

b. Intersite frequency engineering. Use the same procedure as described in paragraph 1204.

FIGURE 12-5. STANDARD RCL FREQUENCY FAMILY FOR 7125-8400 MHz

	Direction A		Direction B	
1.	7160 +	7340 —*	7430 +	7605 —
B.	7205 +	7385 —*	7475 +*	7650 —
C.	7185 +	7365 +	7695 —**	7630 +
D.	7230 +	7135 +	7495 —	7580 +
D.	7230 +	7320 —*	7495 +*	7580 —
E.	7685 —	7805 +	8170 +	8290 —
E.	7685 —	7805 +	8170 +	8045 +
F.	7745 +	7865 —	8230 —	8350 —
F.	7745 +	7865 —	8230 —	8105 +
G.	7725 +	7845 —	8210 +	8330 —
G.	7725 +	7845 —	8210 +	8085 +
H.	7785 +	8270 —	8145 —	8390 +
J.	7765 +	7885 —	8250 —	8370 —
J.	7765 +	7885 —	8250 —	8125 +
K.	7705 +	7825 +	8190 +	8310 -
K.	7705 +	7825 +	8190 +	8065 +

Notes:

(1) * Indicates a "flopped" LO. This option was not initially manufactured for this LO, but it can be ordered.

(2) ** Indicates a new frequency, not previously assigned to the RML standard family.

(3) Direction A or B is a set of Tx's and Rx's in one direction of a hop.

(4) Before using the above sets of frequencies together within the same link or on parallel links, they must be checked for back-to-back and front-to-back separations.

(5) The table does not assume or imply exclusive FAA use.

(6) See figure 12-5 for examples of selection and tests. Frequencies are taken from the standard chart. Test 4 results show Tx frequencies do not fall on critical frequencies. Test 5 results show Tx frequencies fall outside image band plus separation band.

(7) The symbols "+" or "—" indicate that the preferred LO is located on the high or low side of the operating frequency, respectively.

(3). The antenna front-to-back ratio must also be considered. That ratio is defined as the ratio of the power transmitted by the front side of the antenna to the power transmitted by the back. **For a 1 W or 5 W Tx** with a standard antenna, the transmitted frequencies must be separated from other cosite frequencies by at least 30 MHz; **with a high performance antenna**, 10 MHz.

(4) A computer program that aids in performing all of the above tests has been developed by ASR.

(5) The standard RCL frequency family is shown in figure 12-5. This table was developed from the standard frequency family of RML-1, -2, -3 and 4. See also figure 12-6.

(6) The preferred LO is indicated following the frequency. The "+" indicates the LO is on the high side of the operating frequency, the "—", the low side.

FIGURE 12-6. SAMPLE OF FREQUENCY SELECTION, TEST 4 AND 5

```
                                          -----------Test 4 ----------
-------->  Tx  7160 +          Rx 1 =  7430      Rx 2 = 7605
-------->  Tx  7340 —                   -80               +80
<--------  Rx  7430 +                   7350              7685
<--------  Rx  7605 —              (image is on the opposite side)

                                          ----------Test 5-----------
                                Tx 1 = 7430 +     Rx 2 = 7605 —
                 (image band 140 MHz) +140               -140
                    (30 MHz reqd sep.)   + 30             -30
                                        7600              7435
```

c. Hybrid frequency/space diversity. See paragraph 1211.

1208. FREQUENCY ENGINEERING FOR LDRCL IN THE 7125-8500 MHZ BAND. This considers the ALCATEL equipment requirements.

a. Cosite frequency engineering.

(1) The ALCATEL equipment frequency selection criteria consists of 6 tests. These tests apply to the Tx's and Rx's using a common wave guide and antenna configuration.

Test 1. **Space bands** - must be located outside of bands 7250-7300 and 7900-8025 MHz.

Test 2. **Rx local oscillator (LO)** - must be within the band 7125-8500 MHz.

Test 3. **Tx-to-Tx frequency separation** must be 30 MHz or greater.

Test 4. **Rx-to-Rx frequency separation** must be 15 MHz or greater.

Test 5. **Tx-to-Rx frequency separation**. The Tx frequency must have at least 40 MHz separation from the Rx input frequency. If the Rx is at 8200, the Rx + LO at 8270, then a Tx is not permitted between 8160 and 8240 GHz.

Test 6. **A third-order intermod** is not permitted within 15 MHz of the Rx input frequency.

(2) Once the 6 tests in subparagraph (1) above have been satisfied for the Tx's and Rx's on a common antenna, the back-to-back coupling must be considered. Back-to-back coupling is the fraction of power received by a second antenna located on the same tower but facing in a different direction from the Tx antenna and using a separate wave guide. The following specifications assume an angular azimuth separation of at least 15 degrees.

(a) It is recommended that the Tx output frequencies must be separated from the other cosite frequencies by at least 40 MHz.

(b) With a high performance antenna, only 25 MHz separation is required.

b. Intersite frequency engineering. Use the same procedure as described in paragraph 1204.

c. Hybrid frequency/space diversity. See paragraph 1211.

1209. FREQUENCY ENGINEERING FOR THE 14.5000-14.7145 AND 15.1365-15.3500 GHZ BANDS.

a. Cosite frequency engineering is unneeded. FAA only uses this band for one-way links to support Digital Bright Radar Indicator Tower Equipment (DBRITE).

b. Intersite frequency engineering. This frequency band and associated equipment are normally considered limited to a 20 mile one-way path with not more than two repeaters. See paragraph 1204, except limit search to 10 miles.

c. An international conference changed the band, by taking the portion 14.7145-15.1365 GHz and allocating it to Mobile as the Primary service. A new family of frequencies was established to protect that subband. The frequency family plans are shown in figures 12-7.

d. The TML equipment frequency coverage limitation prohibits use of the TML equipment between 15.25-15.35 GHz.

FIGURE 12-7. CURRENT TML CHANNELIZATION PLAN

MHz	MHz	MHz	MHz
14501.25*	15141.25*	14606.25	15246.25
14503.75	15143.75	14608.75	15248.75
14506.25	15146.25	14611.25	15251.25**
14508.75	15148.75	14613.75	15253.75**
14511.25	15151.25	14616.25	15256.25**
14513.75	15153.75	14618.75	15258.75**
14516.25	15156.25	14621.25	15261.25**
14518.75	15158.75	14623.75	15263.75**
14521.25	15161.25	14626.25	15266.25**
14523.75	15163.75	14628.75	15268.75**
14526.25	15166.25	14631.25	15271.25**
14528.75	15168.75	14633.75	15273.75**
14531.25	15171.25	14636.25	14276.25**
14533.75	15173.75	14638.75	15278.75**
14536.25	15176.25	14641.25	15281.25**
14538.75	15178.75	14643.75	15283.75**
14541.25	15181.25	14646.25	15286.25**
14543.75	15183.75	14648.75	15288.75**
14546.25	15186.25	14651.25	15291.25**
14548.75	15188.75	14653.75	15293.75**
14551.25	15191.25	14656.25	15296.25**
14553.75	14193.75	14658.75	15298.75**
14556.25	15196.25	14661.25	15301.25**
14558.75	15198.75	14663.75	15303.75**
14561.25	15201.25	14666.25	15306.25**
14563.75	15203.75	14668.75	15308.75**
14566.25	15206.25	14671.25	15311.25**
14568.75	15208.75	14673.75	15313.75**
14571.25	15211.25	14676.25	15316.25**
14573.75	15213.75	14678.75	15318.75**
14576.25	15216.25	14681.25	15321.25**
14578.75	15218.75	14683.75	15323.75**
14581.25	15221.25	14686.25	15326.25**
14583.75	15223.75	14688.75	15328.75**
14586.25	15226.25	14691.25	15331.25**
14588.75	15228.75	14693.75	15323.75**
14591.25	15231.25	14696.25	15336.25**
14593.75	15233.75	14698.75	15338.75**
14596.25	15236.25	14701.25	15341,25**
14598.75	15238.75	14703.75	15343.75**
14601.25	15241.25	14706.25	15346.25**
14603.75	15243.75	14708.75*	15348.75**

* These frequencies cannot be used for bandwidths greater than 2.5 MHz.
Total number of channels is 168.

** Due to TML equipment limitations, these frequencies are not usable.

From the radar end, use a 14 GHz frequency. If a repeater is necessary, use the paired 15 GHz frequency for the repeater. If another repeater is required, use another 14 GHz frequency; do not exceed two repeaters.

1210. FREQUENCY ENGINEERING FOR LDRCL IN THE 21.2-23.6 GHZ BAND. This band has a very short propagation characteristic and can best be engineered by assuring that cochannel operations are not within 10 nmi. The frequency plan for LDRCL in this band is shown in figure 12-8.

a. Cosite frequency engineering. For cosite operation, ensure a Tx-Rx frequency separation of at least 1.2 GHz and a Tx-Tx frequency separation of at least 50 MHz.

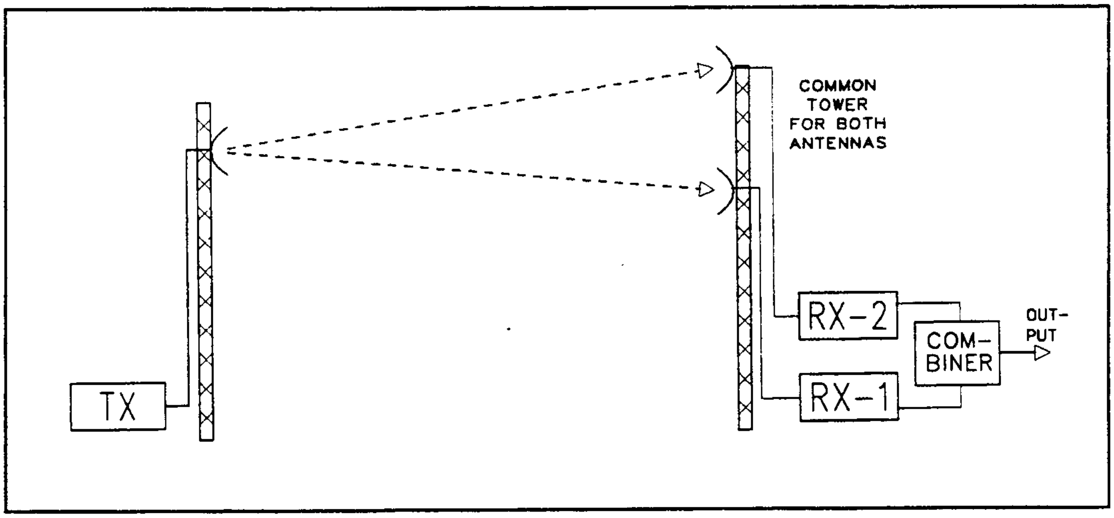
b. Intersite frequency engineering. See paragraph 1204, except limit search to RLOS.

FIGURE 12-8. 21.2-23.6 GHZ LDRCL FREQUENCY ASSIGNMENT PLAN

Freq 1 Paired with (GHz)	Freq 2 (GHz)
21.225	22.425
21.275	22.475
21.325	22.525
21.375	22.575
21.425	22.625
21.475	22.675
21.525	22.725
21.575	22.775
21.625	22.825
21.675	22.875
21.725	22.925
21.775	22.975
21.825	23.025
21.875	23.075
21.925	23.125
21.975	23.175
22.025	23.225
22.075	23.275
22.125	23.325
22.175	23.375
22.225	23.425
22.275	23.475
22.325	23.525
22.375	23.575

1211. SPECIAL PATH CONSIDERATIONS. Although the problem occurs most often on the southern portions of the east and west coast of the contiguous United States and Hawaii, varying path propagation can present real difficulties. There are two ways to alleviate the problem. One is space diversity and the other is frequency diversity. Because space diversity takes no additional frequencies, it is preferable. See figure 12-9. In addition, for digital systems, a hybrid combination of both space and frequency diversity can be provided. See subparagraph c.

FIGURE 12-9. SPACE DIVERSITY



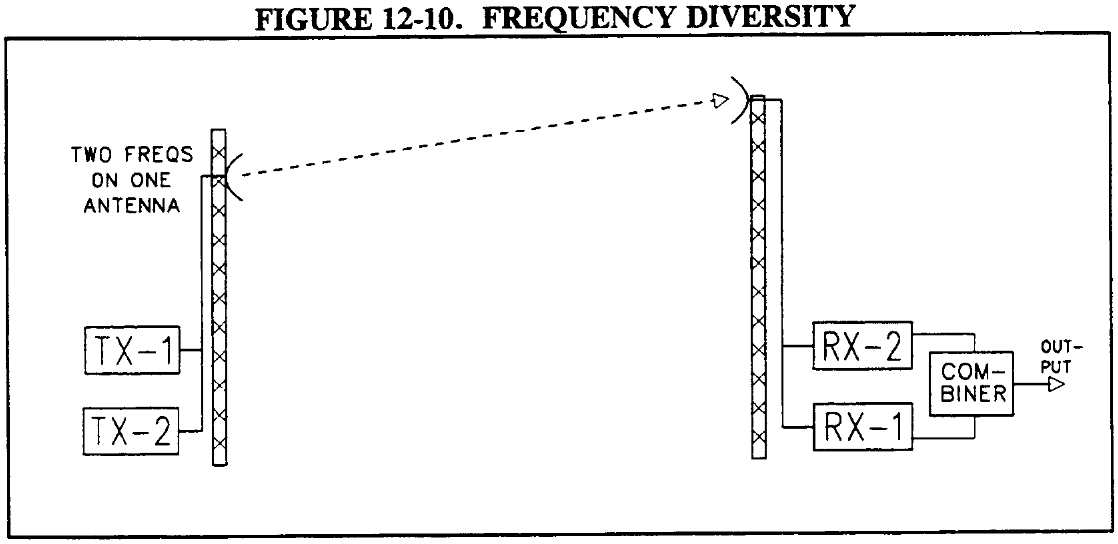
a. **Space diversity** is an effective method to counter multipath fading. It relies on the height dependence of the maxima and minima of the multipath interference patterns. By using the combined or switched output of two antennas separated vertically by many wavelengths, significant improvement can be achieved.

(1) **If the antennas have sufficient separation**, fades on one path will be accompanied by an enhanced signal on the other path. Vertical antenna separation of 30 to 35 feet for RCL and 25 to 35 feet for TML should be adequate. Best performance will be obtained if the second antenna is placed directly above the original clear path antenna. However, tower height restrictions or costs may prohibit this option.

(2) **Satisfactory performance** can usually be obtained when the spacing between antennas is split above and below the original clear path. In this case, it will be necessary to check for problems due to nearby obstacles close to the lower antenna path to assure a still clear path.

(3) **To have space diversity** in one direction of the link, the spaced antennas are associated with the Tx's. For more severe fading problems, spaced antennas are placed at both ends of the link.

FIGURE 12-10. FREQUENCY DIVERSITY



b. The RCL and LDRCL use frequency diversity. A diagram of such a system is shown in figure 12-10.

c. A hybrid system of combined frequency/space diversity for digital systems for the 7125-8500 GHz band also can be provided.

(1) In a hybrid diversity configuration, one antenna is installed at one end of the path (Site A) and two antennas are installed at the other end of the path (Site B). Two different frequencies are transmitted from the common antenna at Site A and received on the two different frequencies at Site B. As a result, the direction of transmission from A to B is similar to normal space diversity. In the reverse direction, one frequency is transmitted from the bottom antenna. Both frequencies are received at the common antenna Site A and switched.

(2) In both directions of transmission, there is a physical separation between the propagation paths. There is a true space diversity improvement in both directions. Since the different paths also operate at different frequencies, there is also frequency diversity improvement.

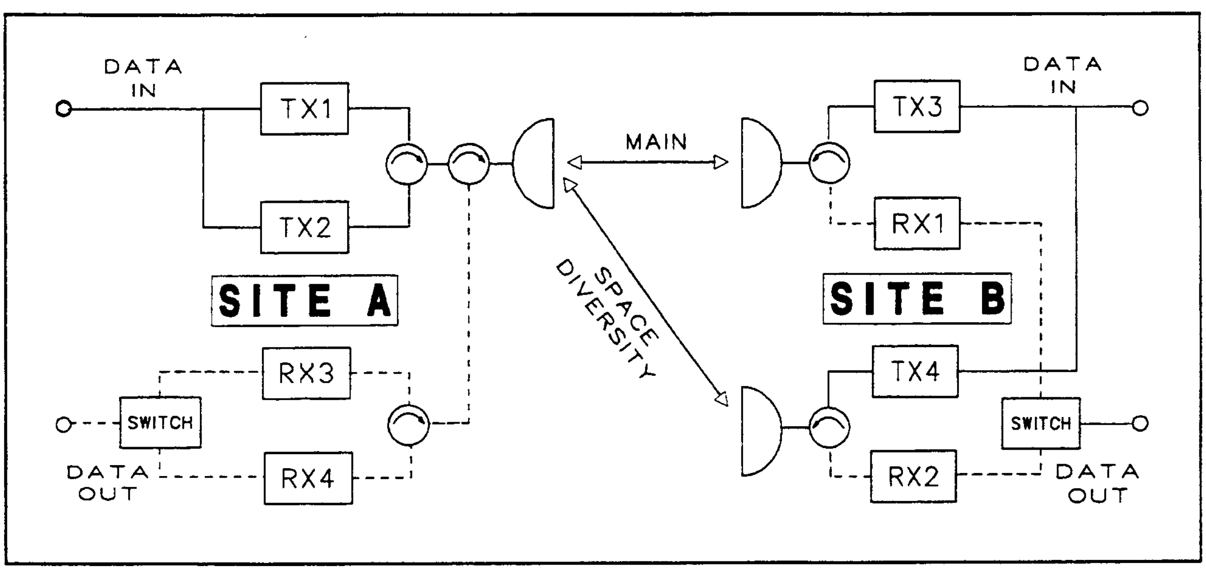
(3) Cosite frequency engineering for the digital hybrid system is different from analog engineering.

(a) Transmitter to transmitter (Tx/Tx) frequency separation shall be ³ 50 MHz.

(b) Receiver to receiver (Rx/Rx) frequency separation shall be ³ 50 MHz.

(c) Transmitter to receiver (Tx/Rx) frequency separation shall be ³ 115 MHz.

FIGURE 12-11. HYBRID FREQUENCY/SPACE DIVERSITY



1212. PATHS WITH BUILT-IN REFLECTORS. Reflectors are a way to put the beam path where it is needed when there is an obstacle in the way, or where considerable height is needed while avoiding a long wave guide run.

a. Called a periscope antenna, an example is shown in figure 12-12. A parabolic antenna is positioned to beam upwards to illuminate a passive reflector at the top of the tower. This avoids problems and costs associated with long runs of wave guide with minimal change in net gain. When properly designed, only first Fresnel zone energy is reflected, thus avoiding phase cancellation from the out-of-phase second zone energy. The design produces a sharper beam and a 2 or 3 dB gain.

FIGURE 12-12. PERISCOPE OR TOP REFLECTOR ANTENNA SYSTEM

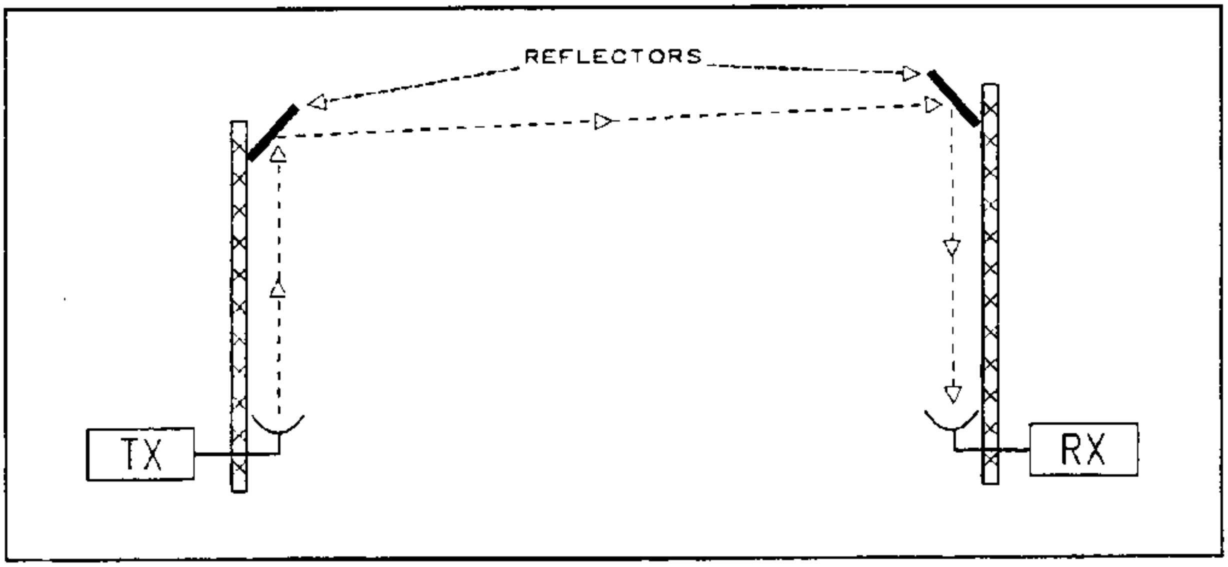


FIGURE 12-13. SINGLE BILLBOARD PASSIVE ANTENNA

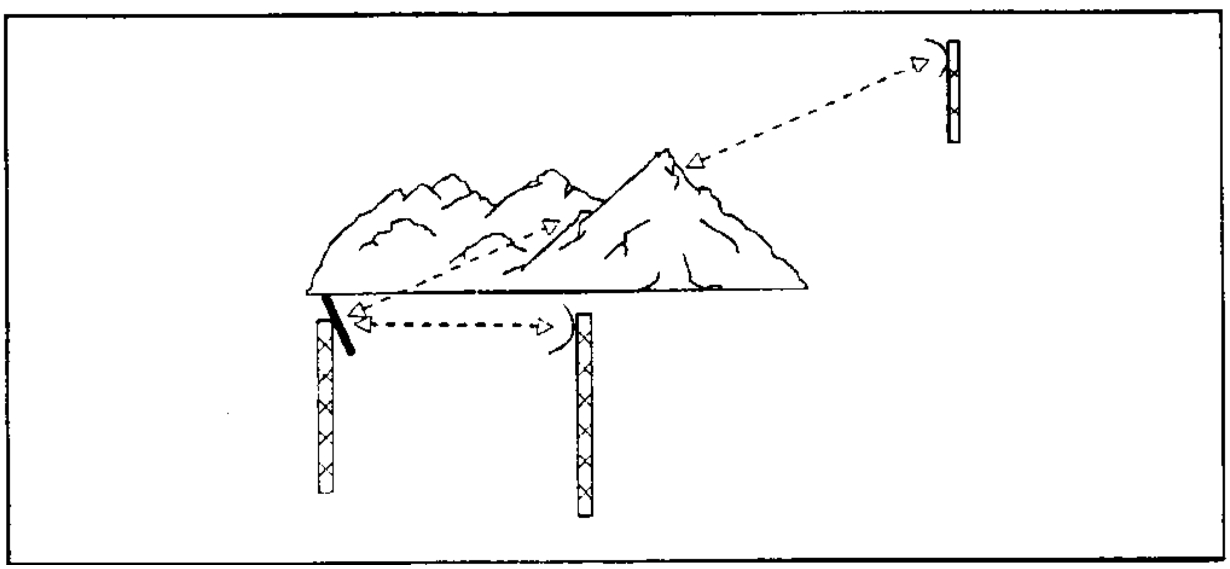
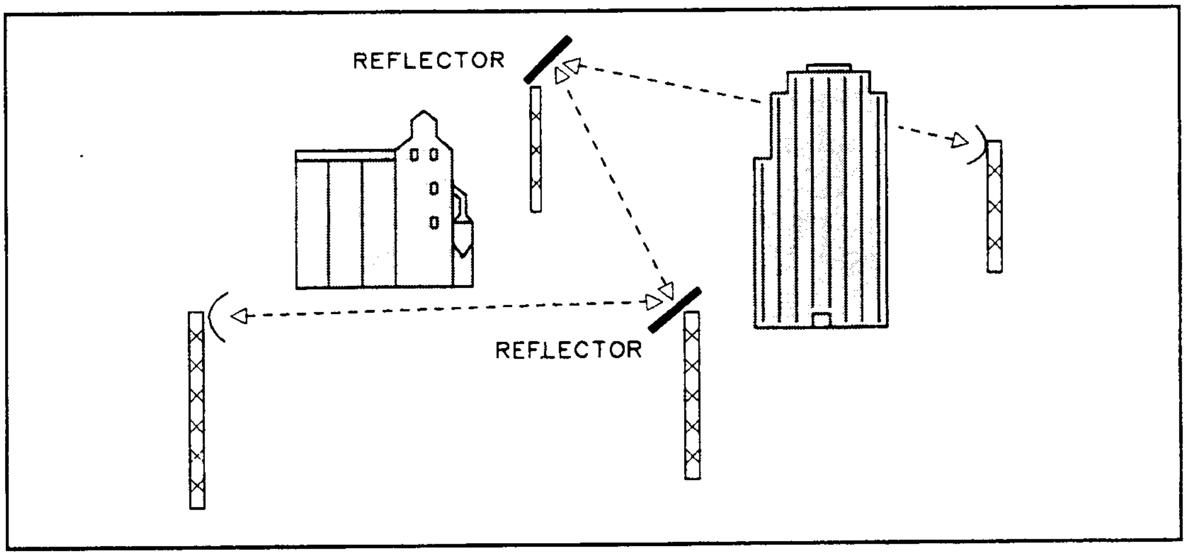


FIGURE 12-14. DOUBLE BILLBOARD PASSIVE ANTENNA



b. Billboard passive repeaters are used for links where terrain, foliage or man-made obstacles prevent a direct RLOS between desired sites. Figure 12-13 depicts single and figure 12-14 depicts double billboard configurations. Here again, both the original and reflected paths must be considered, both for satellite conflict and for the possibility of line-of-sight interference to another user on the same path. That is, not only the billboard reflected path must be checked, but also the azimuth "direct" path of the transmitted signal as it points at the billboard reflector. In Figure 12-13, that is the Tx/Rx azimuths between the billboard tower and the foreground tower as well as the azimuths through the mountains path.

1213. DOCUMENTATION.

a. The IRAC application, before the process was automated, required a complete block diagram with frequencies to accompany the application. Subsequent to automation, those diagrams are no longer required, except under certain conditions. See the NTIA Manual, Chapter 9.

b. In the 1710-1850 MHz and 7125-8500 MHz bands (see figure 12-1), no block diagram is required if the agency has coordinated with all agencies whose systems could conceivably be interfered with by the submitted system. If any such systems appear in the frequency search, appropriate coordination shall be accomplished, to expedite the application processing. This is particularly important if the problem system is military. Coordination should be effected with the appropriate agencies, including military. (See chapter 5 of this order.) If coordination can be accomplished, then a statement should be made in Supplementary Details of the application that coordination with (named) agencies has been successfully accomplished, and that no data plots nor coordination contour maps are needed.

c. The 14.50-15.35 GHz and 21.2-23.6 GHz bands are not covered in IRAC's requirement. But it certainly behooves the frequency engineer to do the same coordination, and to include a statement to that effect in the supplemental portion of the application. Completing coordination and so stating will save considerable time in ASR and will permit processing the request much more quickly.

1214. MAPPING.

a. Link systems can become very complex, particularly if there are repeaters, or if any reflectors are used. Research for any new FAA systems must first look at other FAA and other systems to assure compatibility. It is necessary to establish some form of maps on which to plot all regional systems.

b. The format is not specified, but some form of map records for all regional link system shall be maintained. Aeronautical sectional or local maps are excellent, because they have accurate coordinates on them, and make plotting of sites easy. If there are other agencies whose links are in close proximity to FAA physically and frequency-wise, it would be wise to plot at least the essentials on the map too, as a reminder of their existence. Computer-generated maps may be available in the future, based on the GMF.

1215. COMPUTER ANALYSIS AIDS. There exists a large group of computer programs to aid the engineer in setting up a VHF/UHF/SHF link. These programs normally are used by the F & E engineer. But it is the responsibility of the frequency engineer to assure spectrum compatibility. A list of computer programs to assist in this work and a brief description is given in the appendix.

1216. thru 1299. RESERVED.